Supplementary Information. Decision support systems halve fungicide use compared to calendar-based strategies without increasing disease risk

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Supplementary Figures

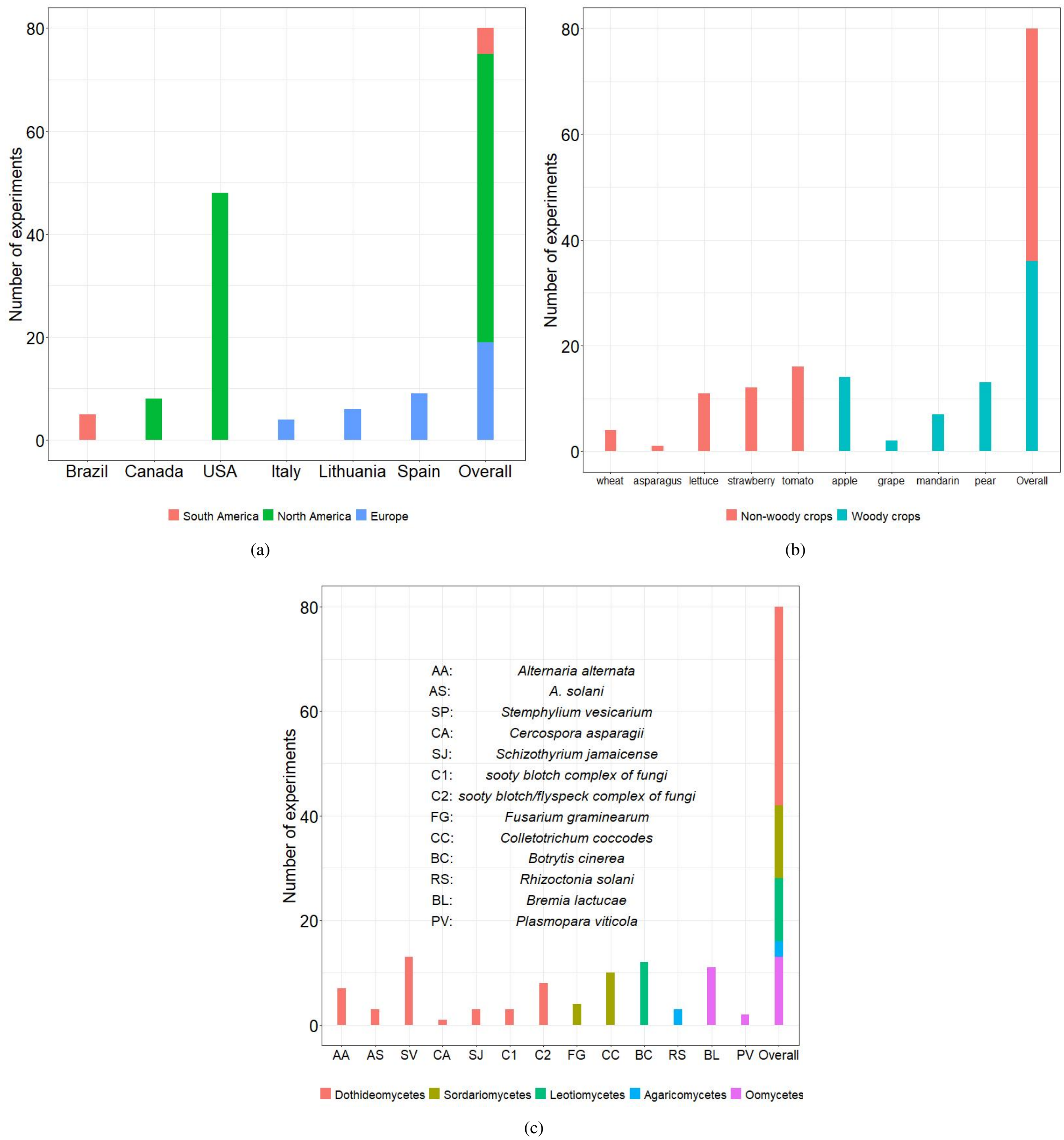
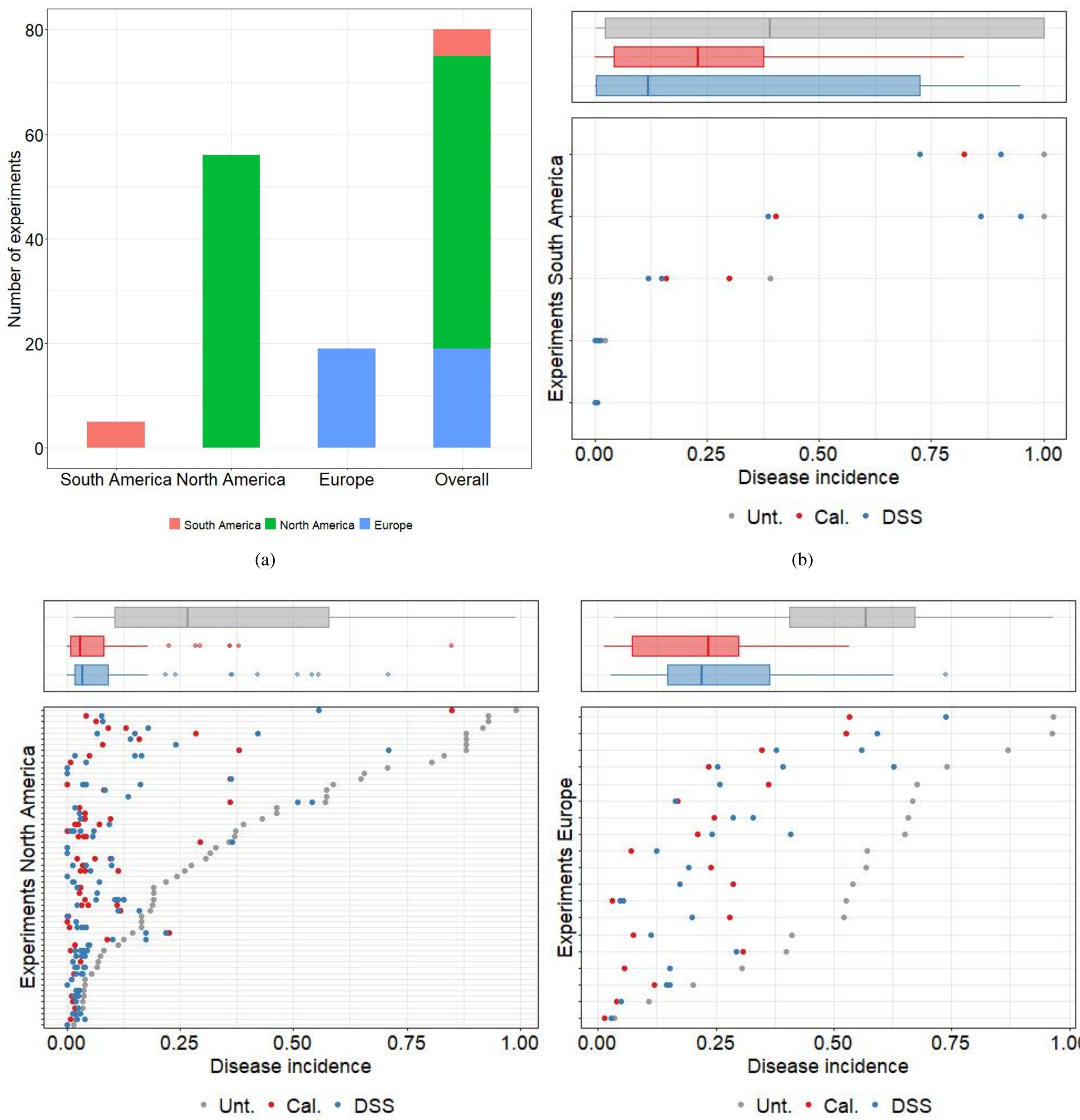


Figure S1. Moderator variable (i.e., location, crop, pathogen, fungicide) categories absolute frequency at experiment level. Marginal and overall distribution of the number of experiments according to: (a) experiment location: Brazil (South America); Canada and USA (North America); Italy, Lithuania and Spain (Europe); (b) crop type: wheat, asparagus, lettuce, strawberry and tomato (non-woody crops); apple, pear, grape and mandarin (woody crops); and (c) pathogen evaluated: *Alternaria alternata*, *A. solani*, *Stemphylium vesicarium*, *Cercospora asparagii*, *Schizothyrium jamaicense* and *Peltaster fructicola* (Dothideomycetes); *Fusarium graminearum* and *Colletotrichum coccodes* (Sordariomycetes); *Botrytis cinerea* (Leotiomycetes); *Rhizoctonia solani* (Agaricomycetes); *Bremia lactucae* and *Plasmopara viticola* (Oomycetes).



(a) (b) (c) (d)

Figure S2. Observed disease incidences in the 80 experiments according to location categories (i.e, South America, North America, Europe). (a) describes the number of experiments for each location category, (b), (c) and (d) describe individual (per experiment) and overall distribution of the disease incidence data for untreated (Unt), calendar-based (Cal) and DSS-based strategies (DSS) for experiments located in South America, North America and Europe, respectively.

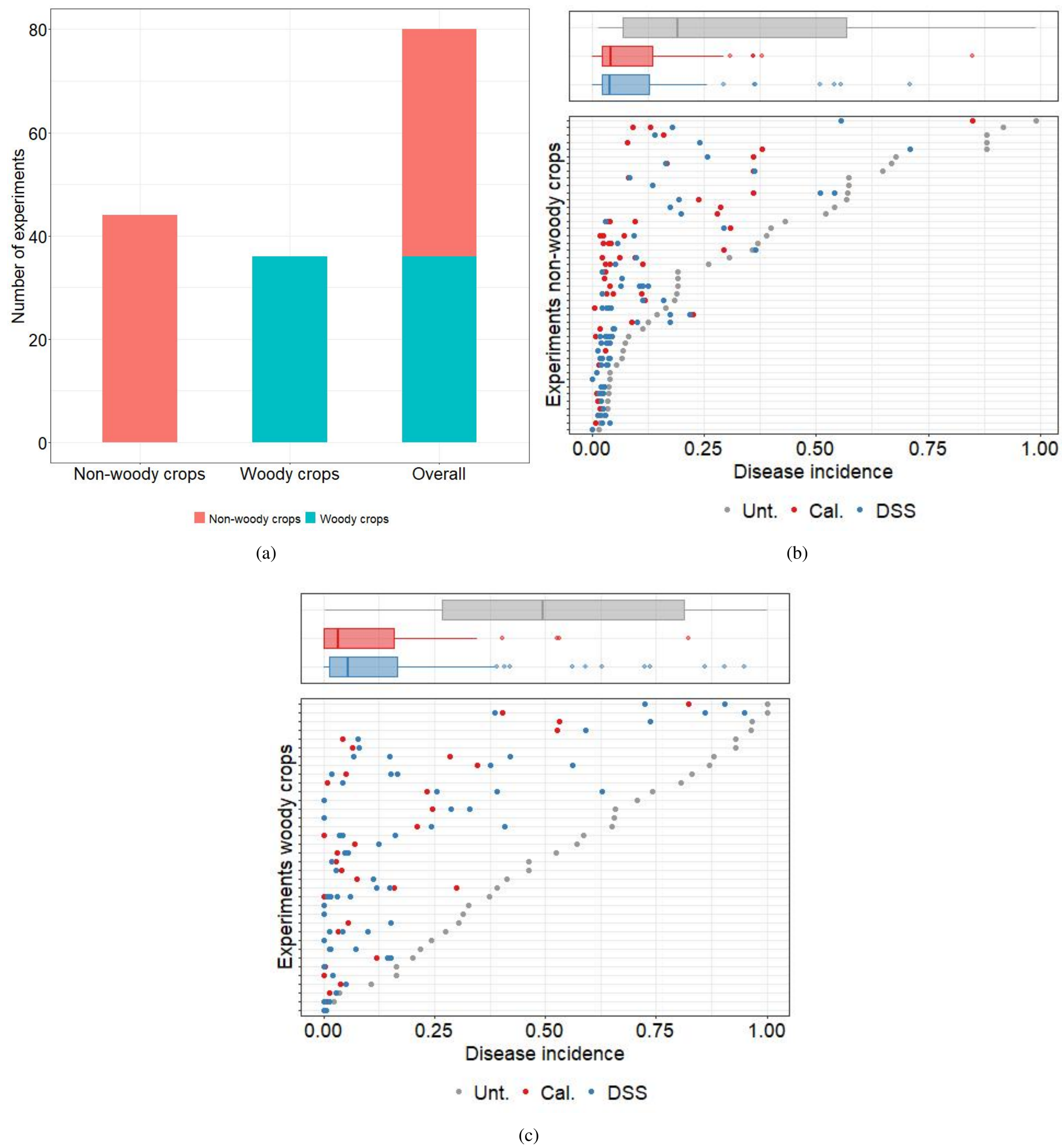


Figure S3. Observed disease incidences in the 80 experiments according to crop type categories (i.e, non-woody crops, woody crops). (a) describes the number of experiments for each crop type category, (b) and (c) describe individual (per experiment) and overall distribution of the disease incidence data for untreated (Unt), calendar-based (Cal) and DSS-based strategies (DSS) for experiments with non-woody and woody crops, respectively.

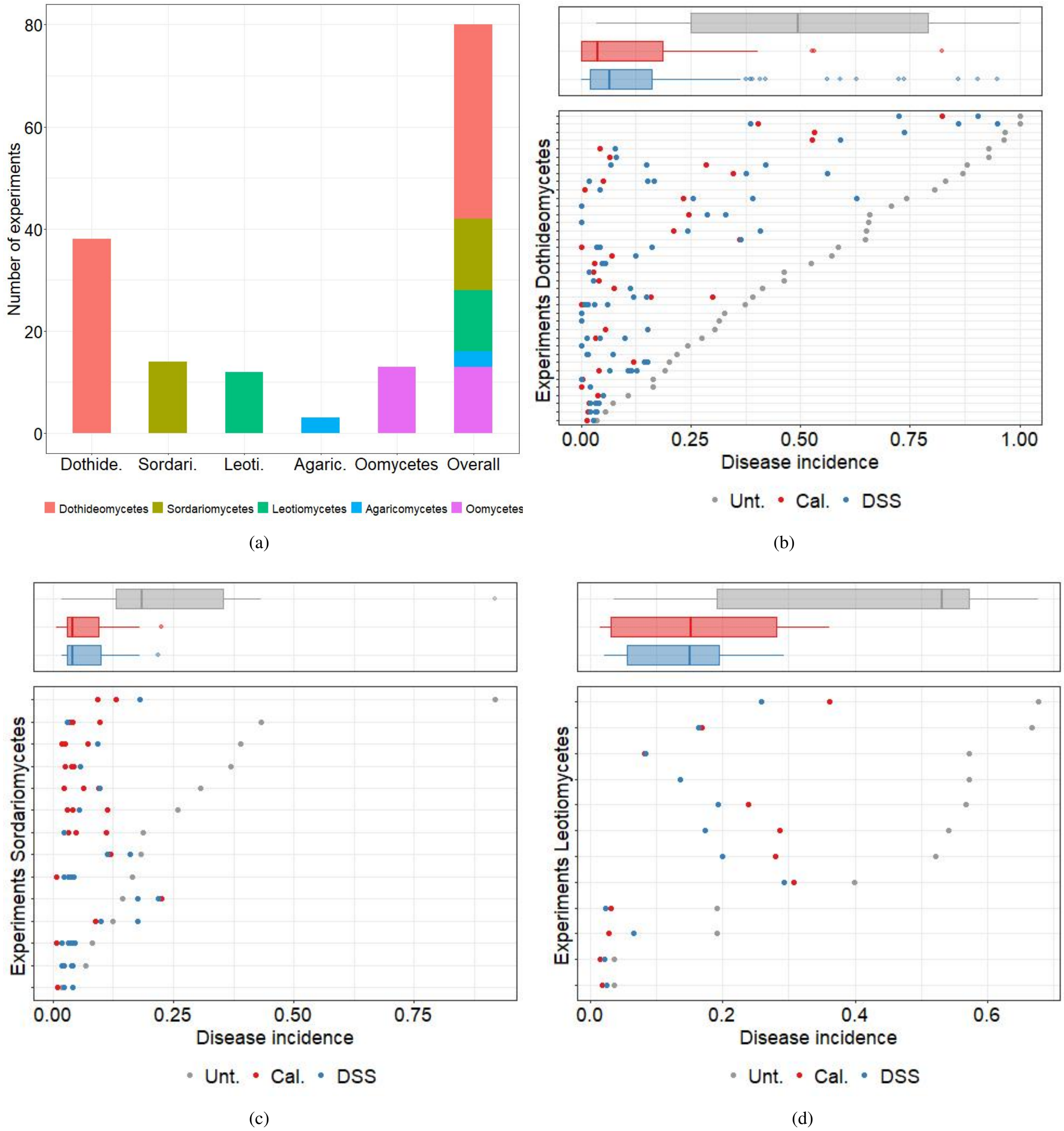
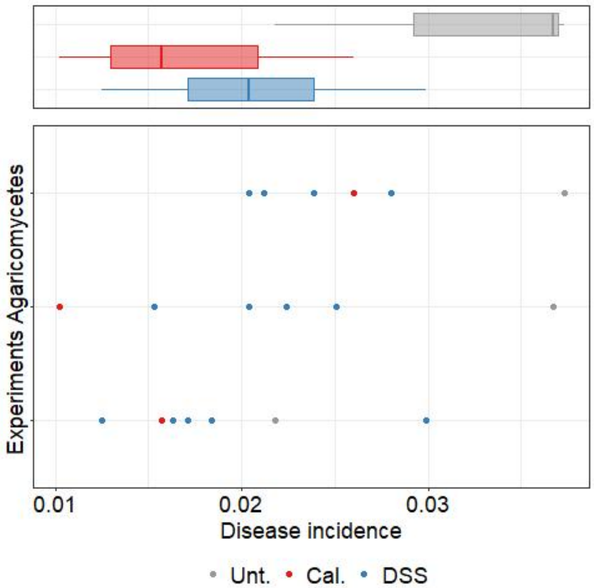


Figure S4. Observed disease incidences in the 80 experiments according to pathogen categories (i.e, Dothideomycetes, Sordariomycetes, Leotiomycetes, Agaricomycetes, Oomycetes). (a) describes the number of experiments for each pathogen category, (b), (c), (d), (e) and (f) describe individual (per experiment) and overall distribution of the disease incidence data for untreated (Unt), calendar-based (Cal) and DSS-based strategies (DSS) for experiments that evaluated Dothideomycetes, Sordariomycetes, Leotiomycetes, Agaricomycetes and Oomycetes, respectively.



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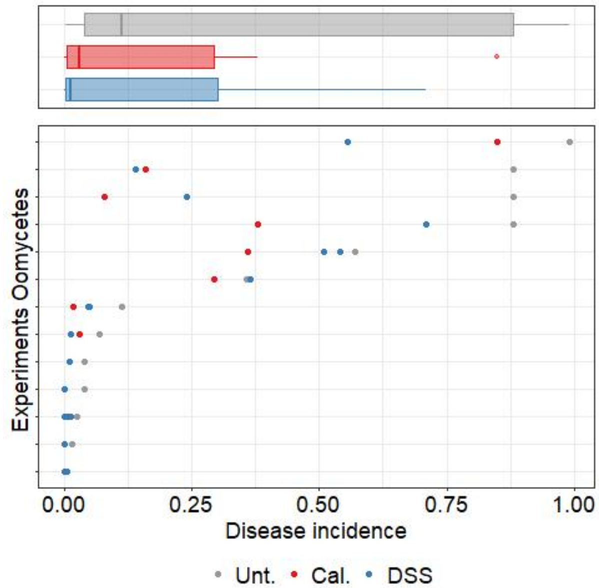


(f)

Figure S4. Observed disease incidences in the 80 experiments according to pathogen categories (i.e, Dothideomycetes, Sordariomycetes, Leotiomycetes, Agaricomycetes, Oomycetes). (a) describes the number of experiments for each pathogen category, (b), (c), (d), (e), and (f) describe individual (per experiment) and overall distribution of the disease incidence data for untreated (Unt), calendar-based (Cal) and DSS-based strategies (DSS) for experiments which evaluated Dothideomycetes, Sordariomycetes, Leotiomycetes, Agaricomycetes and Oomycetes, respectively.

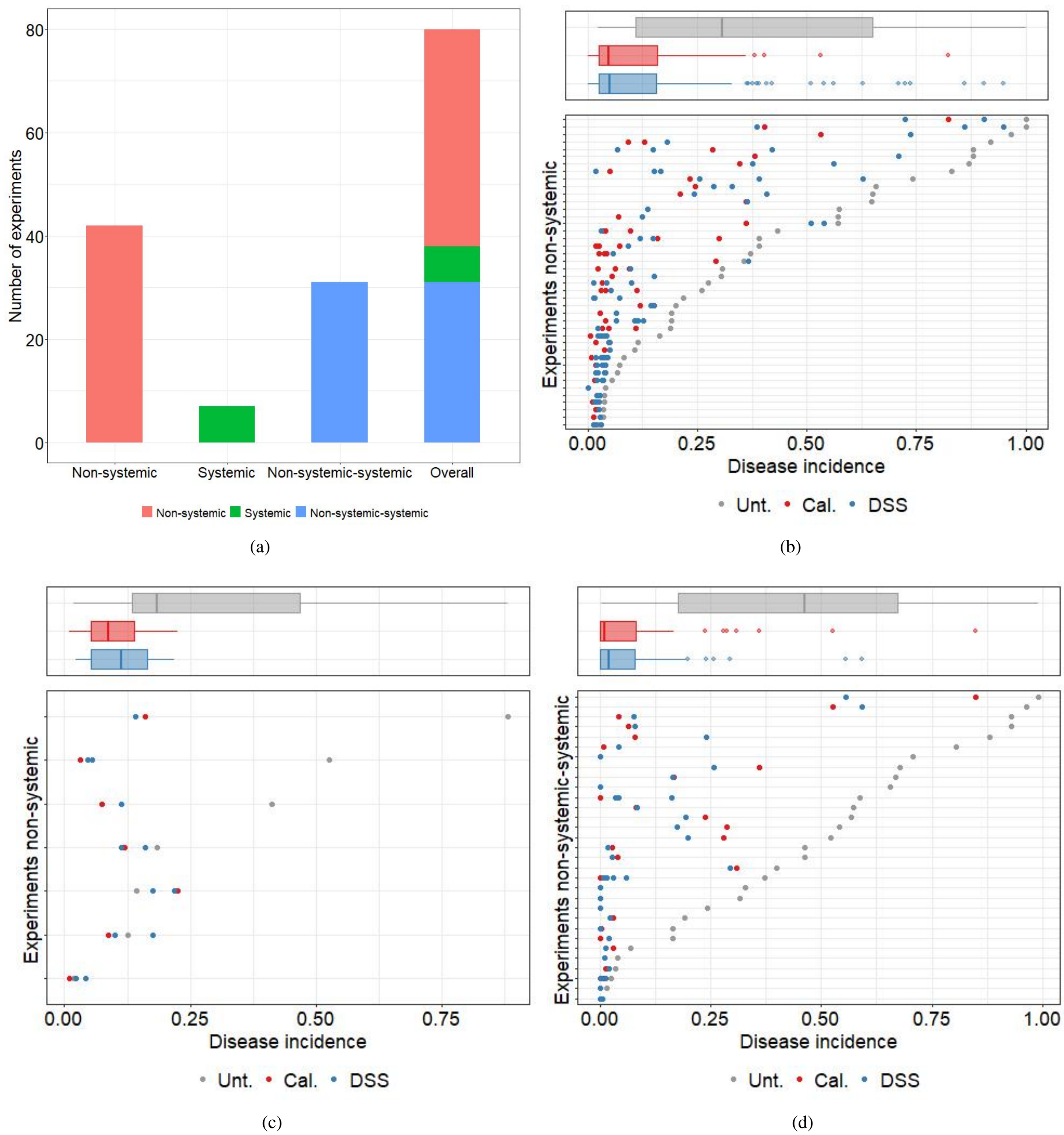
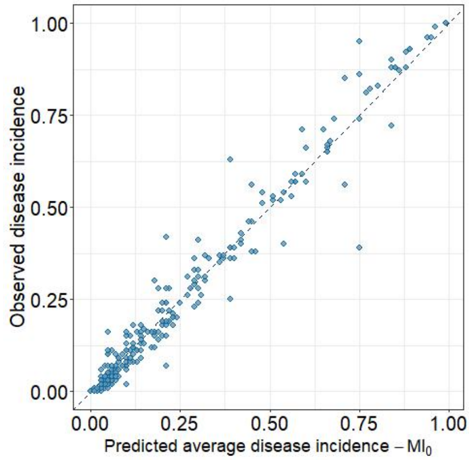


Figure S5. Observed disease incidences in the 80 experiments according to fungicide type categories (i.e., non-systemic, systemic and non-systemic-systemic). (a) describes the number of experiments for each fungicide category, (b), (c) and (d) describe individual (per experiment) and overall distribution of the disease incidence data for untreated (Unt), calendar-based (Cal) and DSS-based strategies (DSS) for experiments that used non-systemic, systemic and non-systemic-systemic fungicides, respectively.



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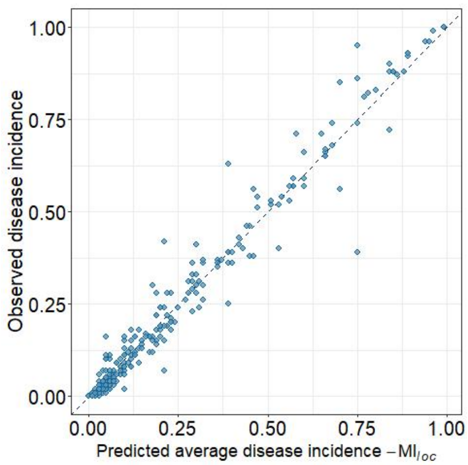

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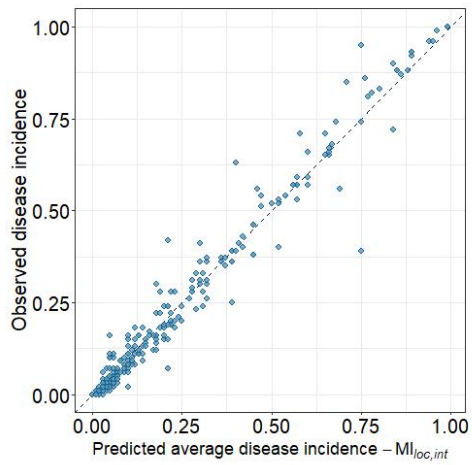

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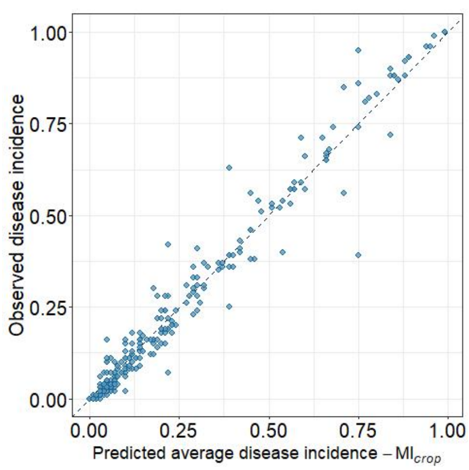

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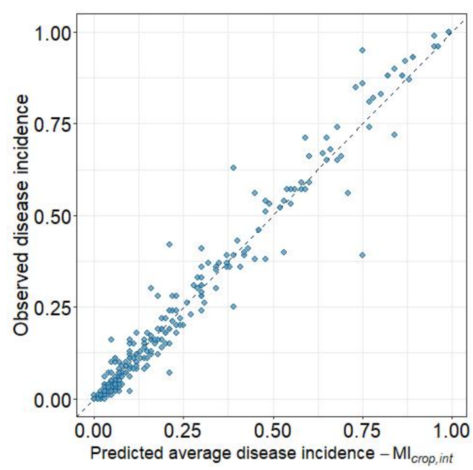

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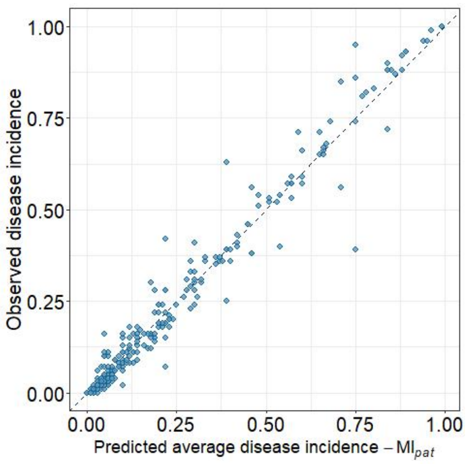
Figure S6. Evaluation of the adequacy and performance of MI models. Observed disease incidence vs. predicted average disease incidence at plot level for the (a) MI_0, (b) MI_{loc}, (c) $MI_{loc,int}$, (d) MI_{crop}, (e) $MI_{crop,int}$, (f) the MI_{pat}, (g) $MI_{pat,int}$, (h) MI_{fun} and (i) $MI_{fun,int}$ models. Dashed line is the regression line 1:1. The predicted average values were drawn from 10 replicated datasets originated from the corresponding model fit. Model specifications are displayed in Table S5.



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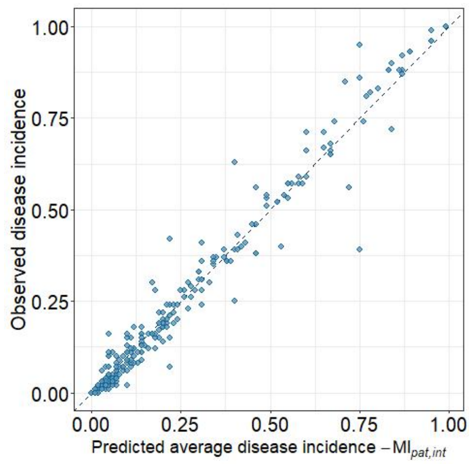

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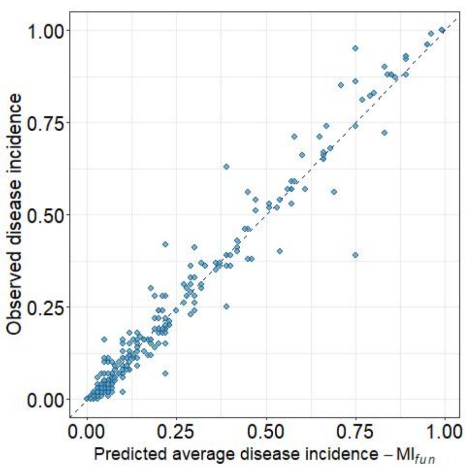

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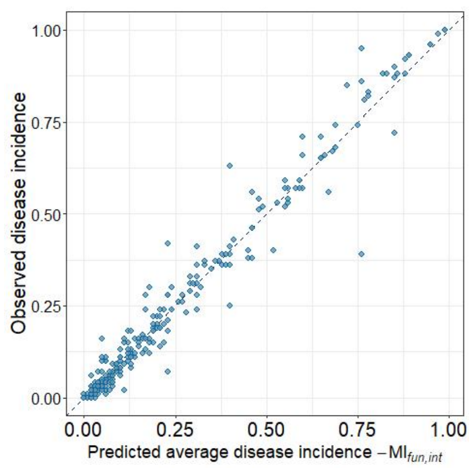

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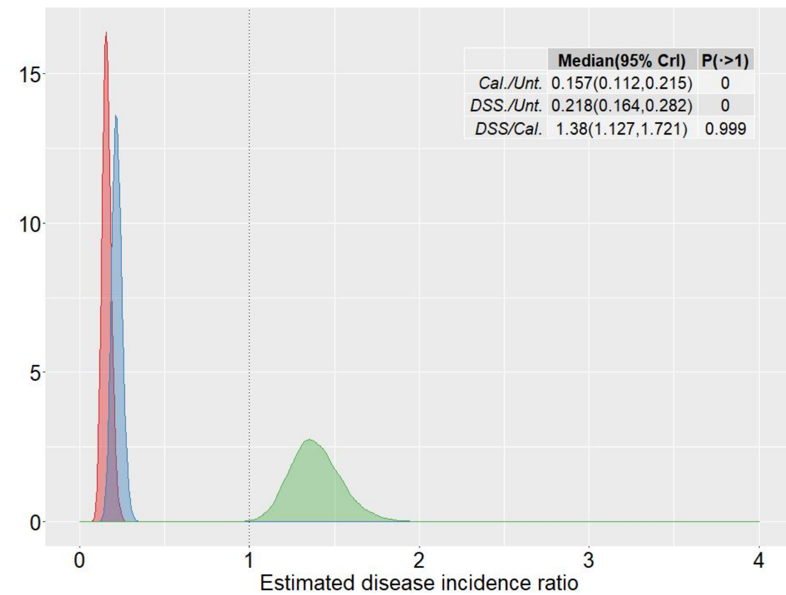
Figure S6. Evaluation of the adequacy and performance of MI models. Observed disease incidence vs. predicted average disease incidence at plot level for the (a) MI$_0$, (b) MI$_{loc}$, (c) MI$_{loc,int}$), (d) MI$_{crop}$, (e) MI$_{crop,int}$, (f) the MI$_{pat}$, (g) MI$_{pat,int}$, (h) MI$_{fun}$ and (i) MI$_{fun,int}$ models. Dashed line is the regression line 1:1. The predicted average values were drawn from 10 replicated datasets that originated from the corresponding model fit. Model specifications are displayed in Table S5.



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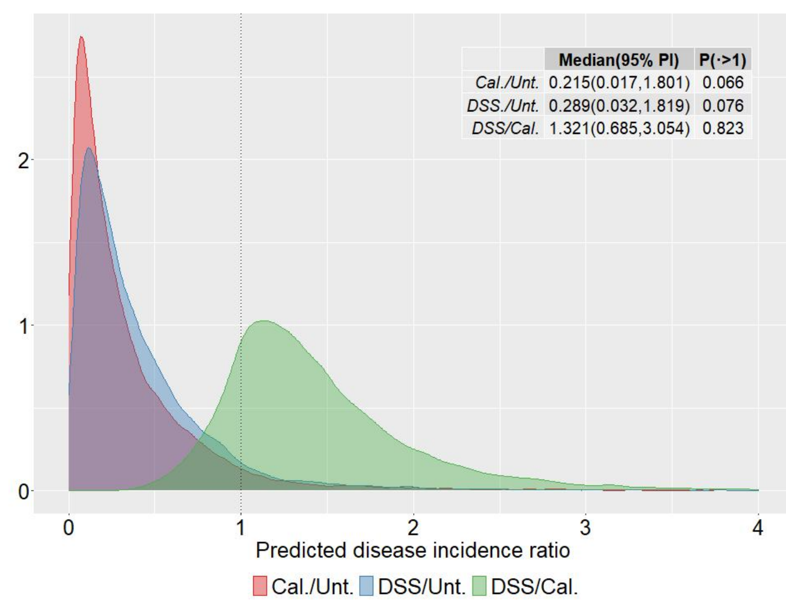
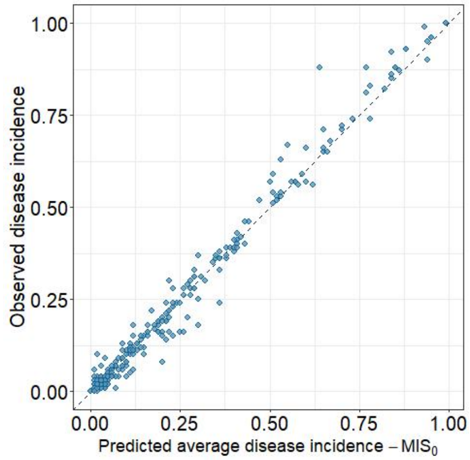


(b)

Figure S7. Probability distributions of disease incidence ratios between calendar-based strategies (Cal), DSS-based strategies (DSS) and untreated controls (Unt). Ratios were computed for Cal vs. Unt (Cal/Unt), DSS vs. Unt (DSS/Unt) and DSS vs. Cal (DSS/Cal) strategies. (a) Describes the distributions of the expected ratios across the experiments included in the dataset and (b) describes plausible ratio values predicted for a new experiment, not yet conducted. Both types of probability distribution are summarised by their medians, 95% probability intervals and probability of the ratios being higher than 1. CrI and PI mean credibility and predictive intervals, respectively. P(.>1) indicates the probabilities of the ratios being higher than 1. Results show that the disease incidence ratio levels achieved with DSS and Cal compared to untreated are very similar and below 1 (median ratios of 0.158 and 0.218 with Cal and DSS, respectively), although the ratio is slightly lower with Cal.



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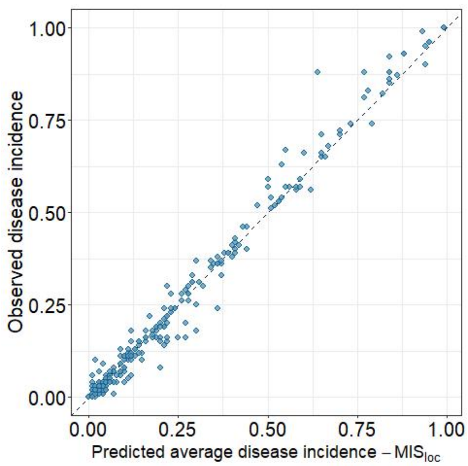

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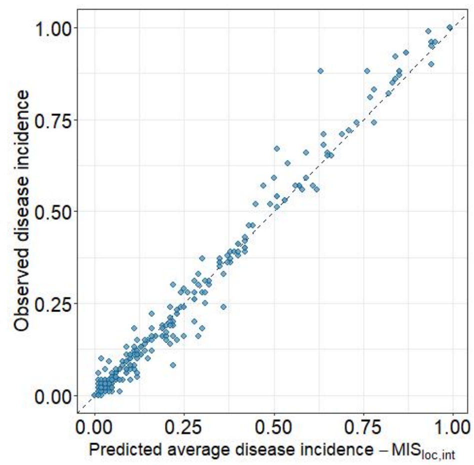

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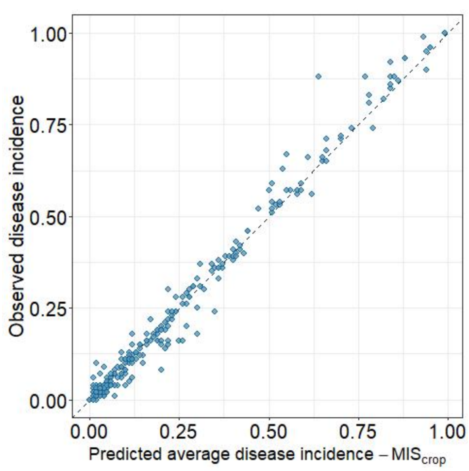

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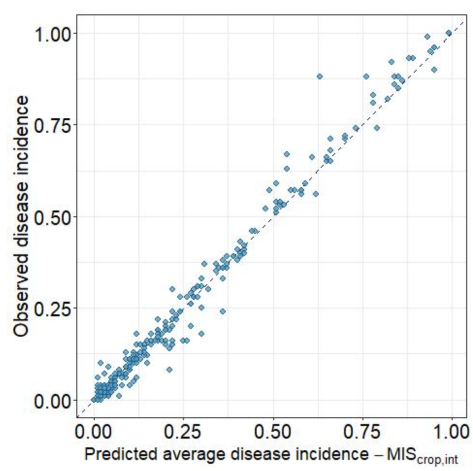
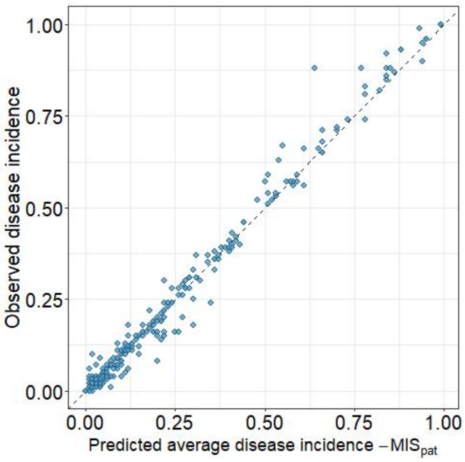


(e)

Figure S8. Evaluation of the adequacy and performance of MIS models. Observed disease incidence vs. the predicted average disease incidence at plot level for the (a) MIS_0, (b) MIS_{loc}, (c) $MIS_{loc,int}$, (d) MIS_{crop}, (e) $MIS_{crop,int}$, (f) the MIS_{pat}, (g) $MIS_{pat,int}$, (h) MIS_{fun} and (i) $MIS_{fun,int}$ models. Dashed line is the regression line 1:1. The predicted average values were drawn from 10 replicated datasets that originated from the corresponding model fit. Model specifications are displayed in Table S7.



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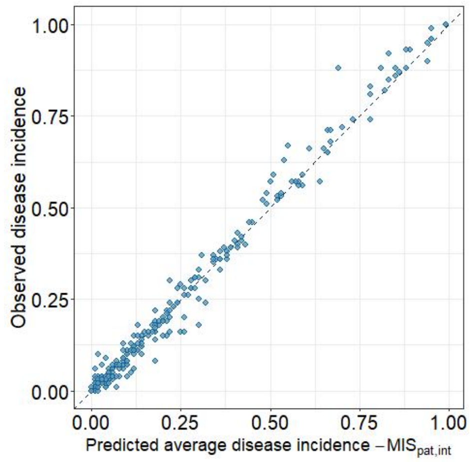

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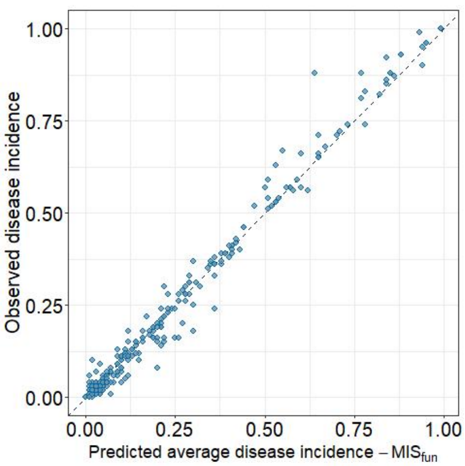

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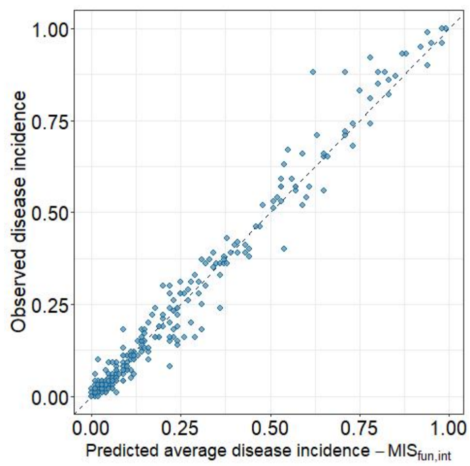
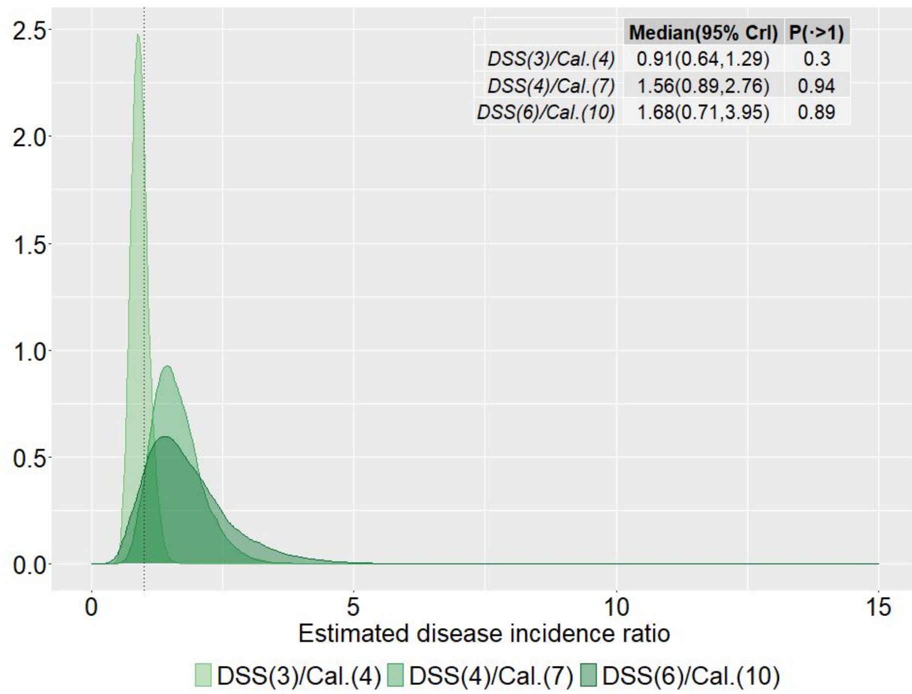
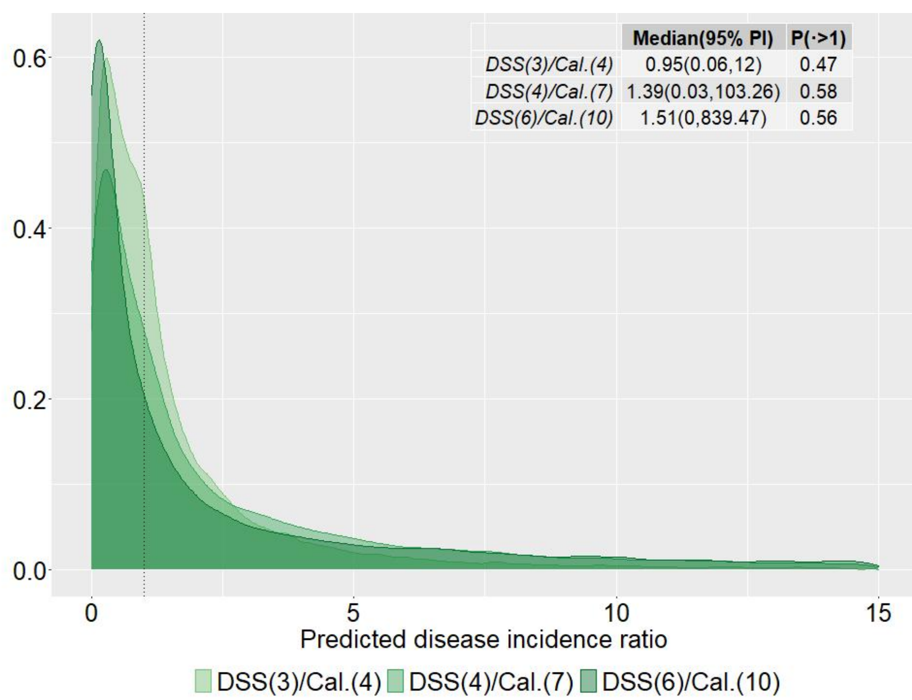


(i)

Figure S8. Evaluation of the adequacy and performance of MIS models. Observed disease incidence vs. predicted average disease incidence at plot level for the (a) MIS_0, (b) MIS_{loc}, (c) $MIS_{loc,int}$, (d) MIS_{crop}, (e) $MIS_{crop,int}$, (f) the MIS_{pat}, (g) $MIS_{pat,int}$, (h) MIS_{fun} and (i) $MIS_{fun,int}$ models. The dashed line is the regression line 1:1. The predicted average values were drawn from 10 replicated datasets that originated from the corresponding model fit. Model specifications are displayed in Table S7.

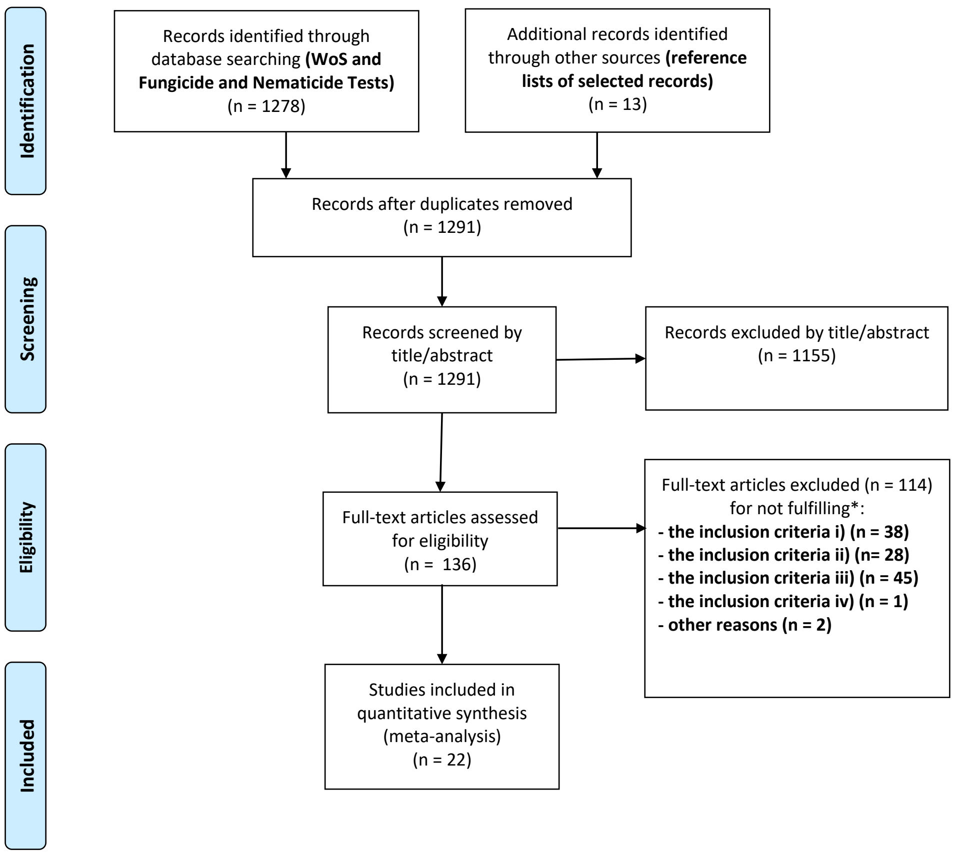


(a)



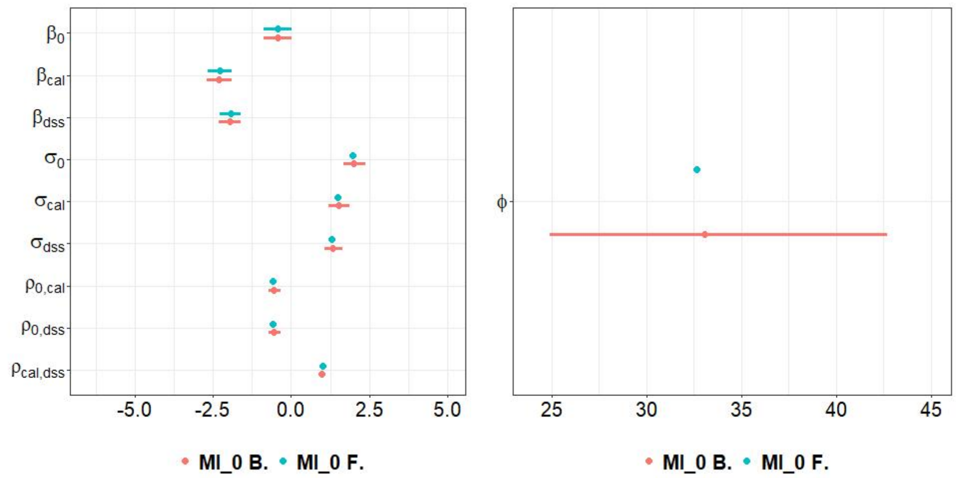
(b)

Figure S9. Probability distributions of disease incidence ratio between DSS-based (DSS) and calendar-based (Cal) strategies considering different observed numbers of sprays. (a) Describes the distributions of the expected ratios across the experiments included in the dataset and (b) describes the plausible ratio values predicted for a new experiment, not yet conducted. In each case, three distributions are reported corresponding to the first (Q_1), second (median) (Q_2) and third (Q_3) quartiles of the observed numbers of sprays for DSS (3, 4 and 6) and Cal (4, 7 and 10) strategies in the 80 experiments. Each probability distribution is summarised by its median, 95% probability interval and probability of the differences being higher than 1. CrI and PI are mean credibility and predictive intervals, respectively. P(·>1) indicates the probabilities of the ratios being higher than 1. All credibility probability intervals include one, revealing that the use of lower numbers of sprays resulting from the DSS strategies does not lead to a substantial increase in disease incidence.



*To be included in the database, articles were required to satisfy the following criteria: i) at least one untreated control (Unt), one calendar-based strategy (Cal) and a DSS-based strategy (DSS) were tested; ii) disease incidence (i.e., proportion of diseased organs); iii) sample size (i.e., total number of organs evaluated) and iv) number of fungicide spray applications were provided for the untreated control and for each fungicide strategy.

Figure S10. PRISMA flow diagram of the procedure used for the selection of experiments in the meta-analysis.



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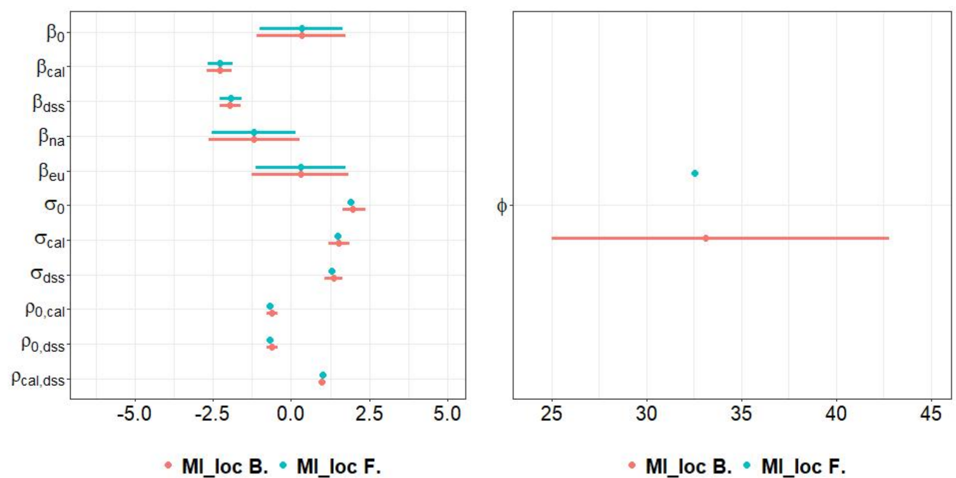

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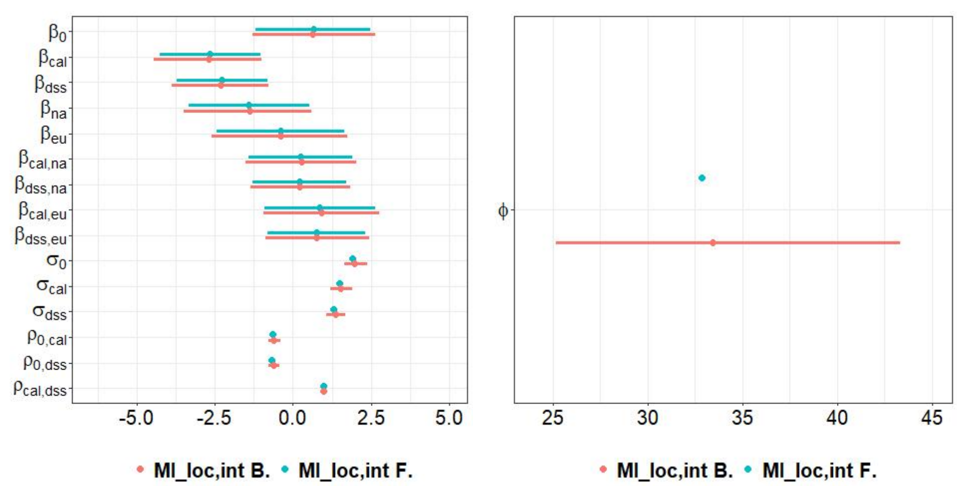
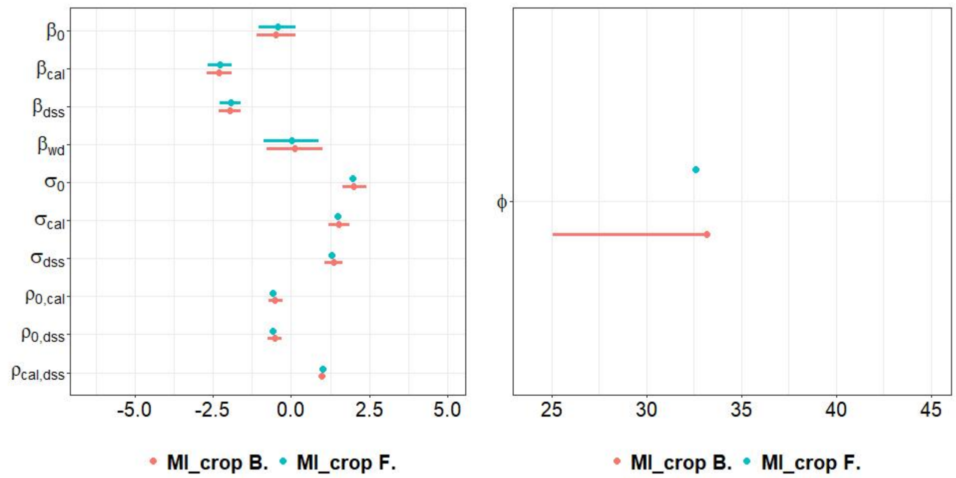


(c)

Figure S11. Sensitivity analysis for MI models. Bayesian parameter estimates (in pink) vs. frequentist parameter estimates (in blue) for the (a) MI_0, (b) MI_{loc}, (c) $MI_{loc,int}$, (d) MI_{crop}, (e) $MI_{crop,int}$, (f) MI_{pat}, (g) $MI_{pat,int}$, (h) MI_{fun} and (i) $MI_{fun,int}$ models. Bayesian parameter estimates are summarised by the mean and the 95% credible interval (95% CrI). Frequentist parameter estimates are summarised by the “estimate” and the 95% confidence interval (95% CI). Model specifications are displayed in Table S5.



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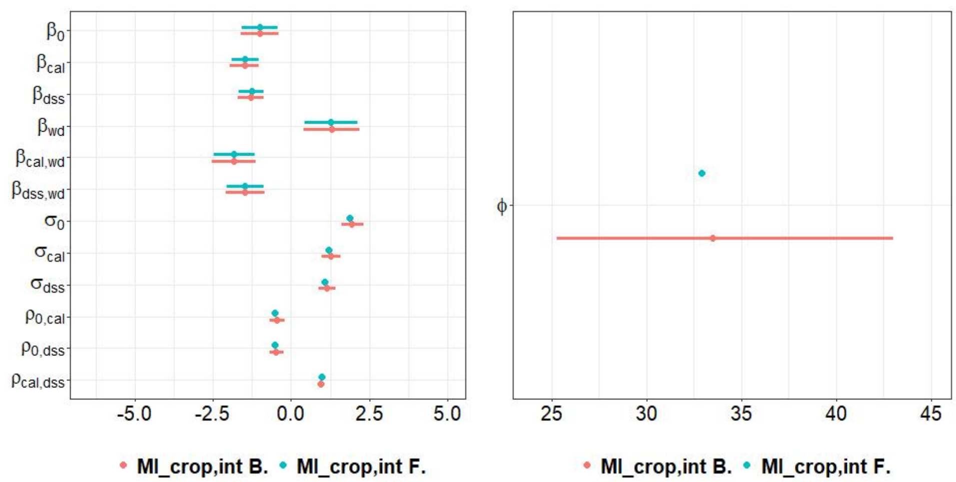

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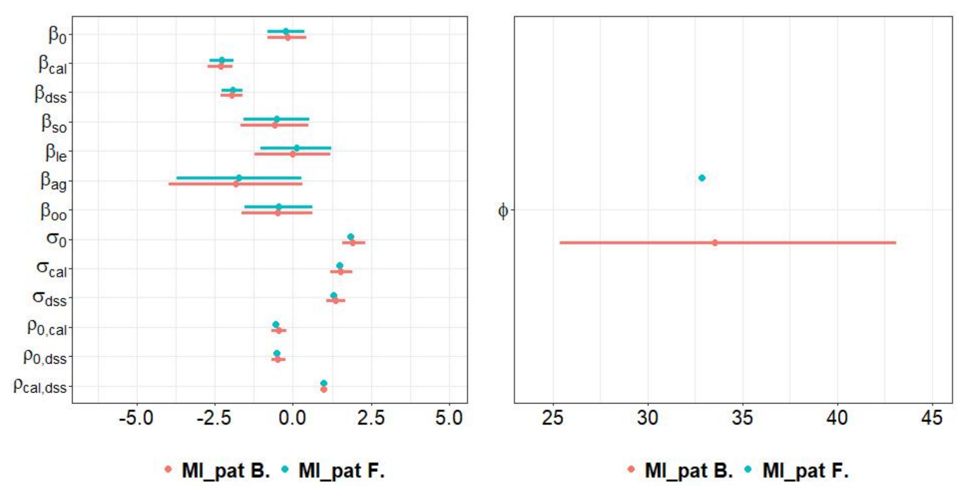

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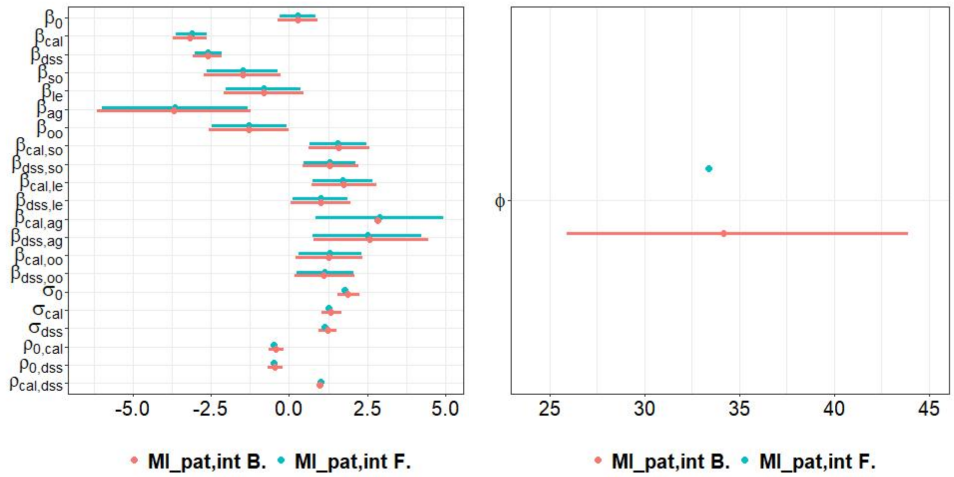

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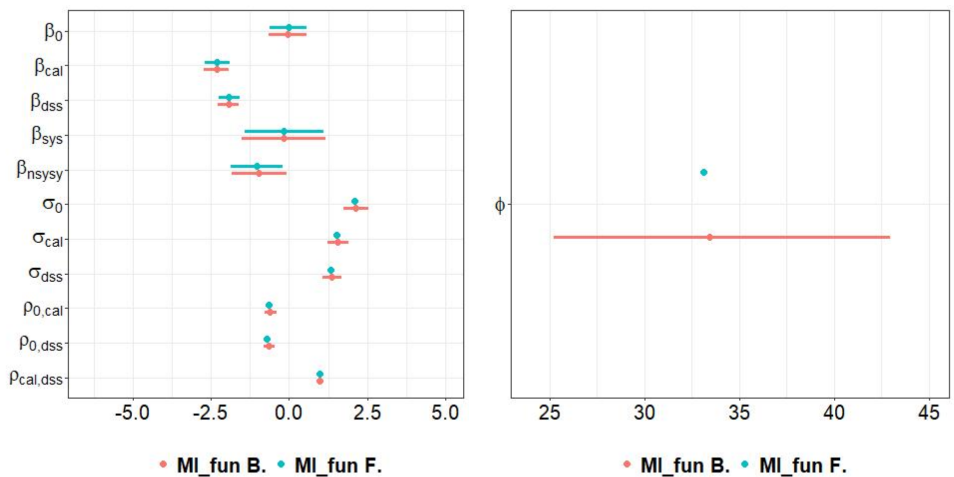

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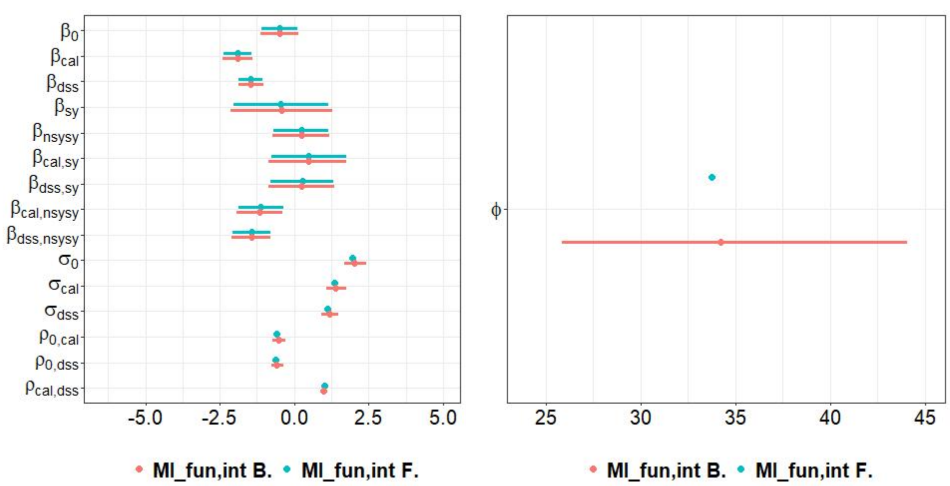

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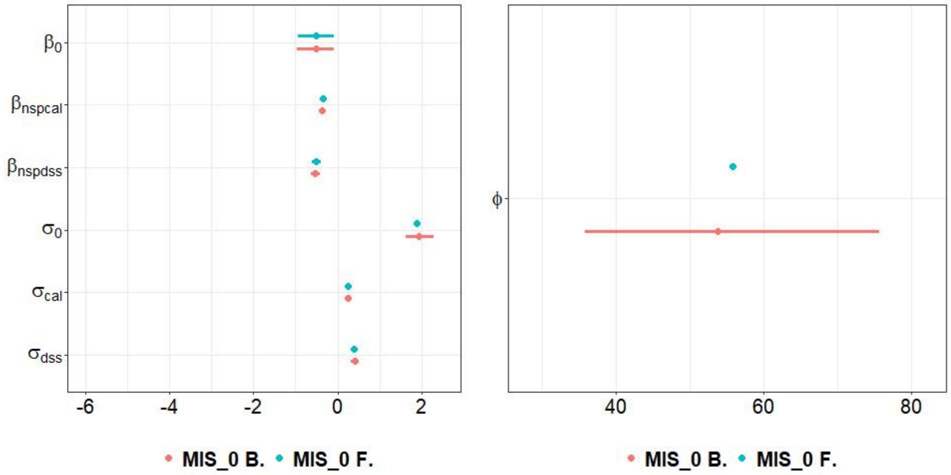

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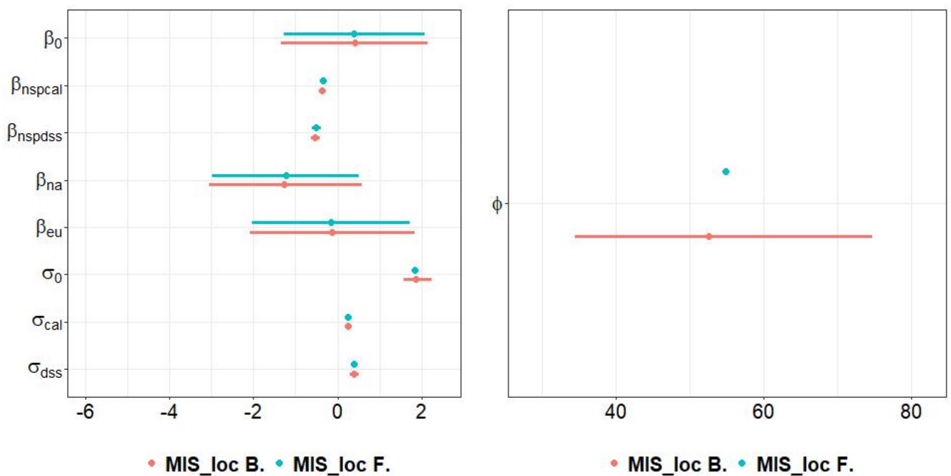

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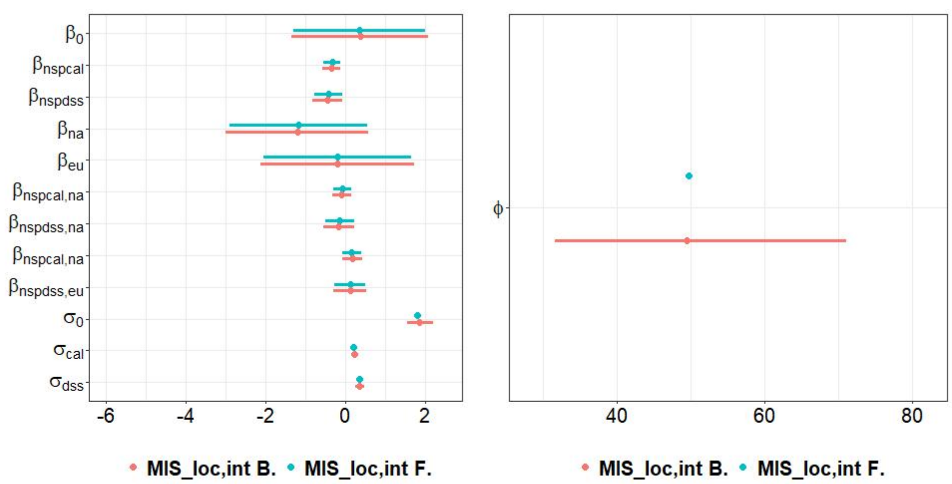
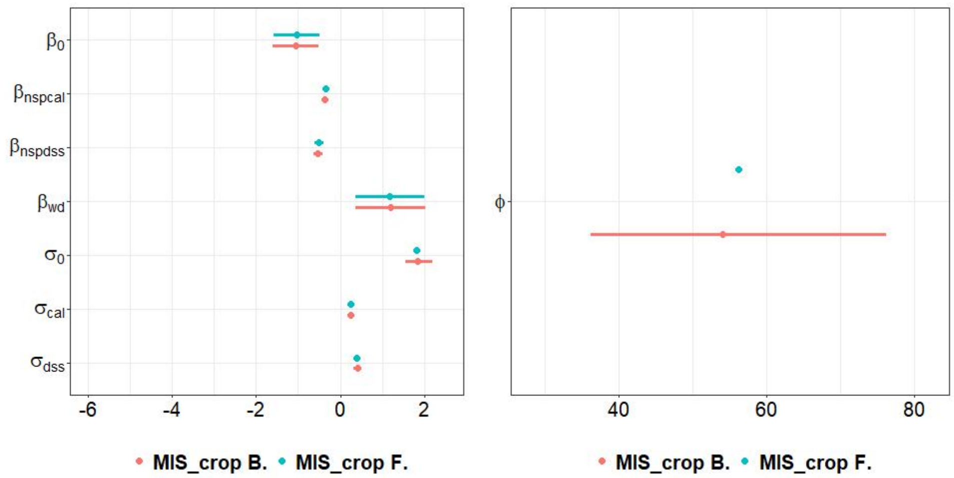


(c)

Figure S12. Sensitivity analysis for MIS models. Bayesian parameter estimates (in pink) vs. frequentist parameter estimates (in blue) for the (a) MIS_0, (b) MIS_{loc}, (c) $\text{MIS}_{loc,int}$, (d) MIS_{crop}, (e) $\text{MIS}_{crop,int}$, (f) MIS_{pat}, (g) $\text{MIS}_{pat,int}$, (h) MIS_{fun} and (i) $\text{MIS}_{fun,int}$ models. Bayesian parameter estimates are summarised by the mean and the 95% credible interval (95% CrI). Frequentist parameter estimates are summarised by the “estimate” and the 95% confidence interval (95% CI). Model specifications are displayed in Table S7.



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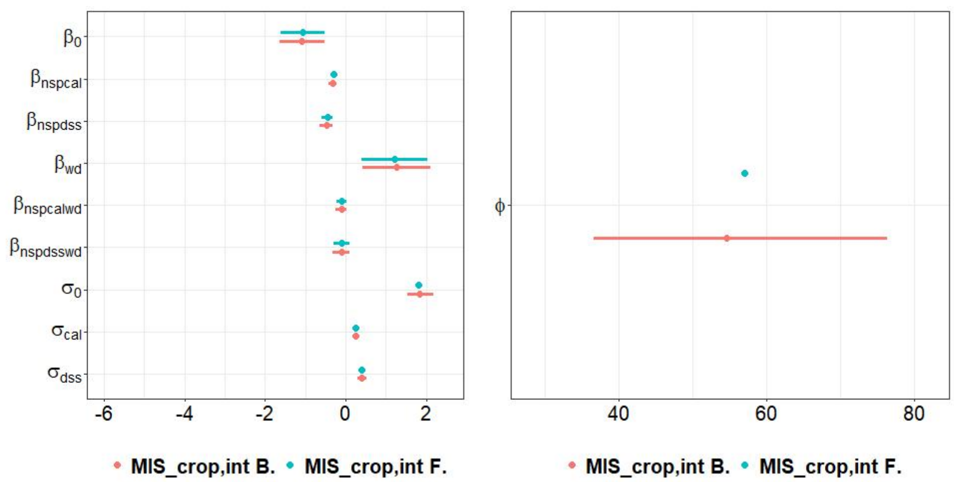

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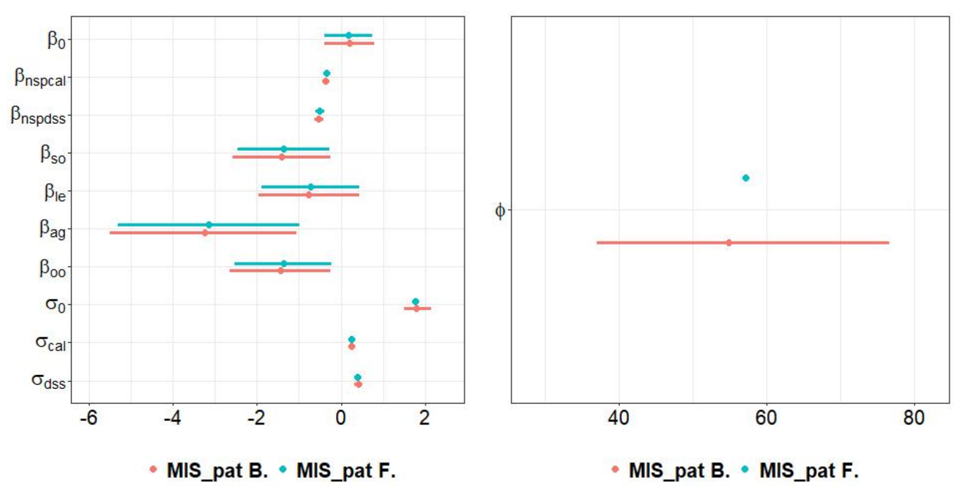

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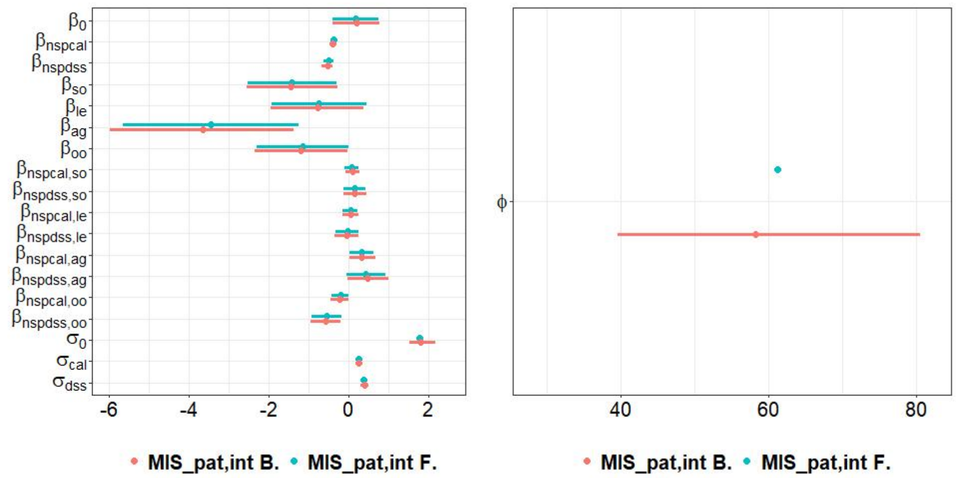
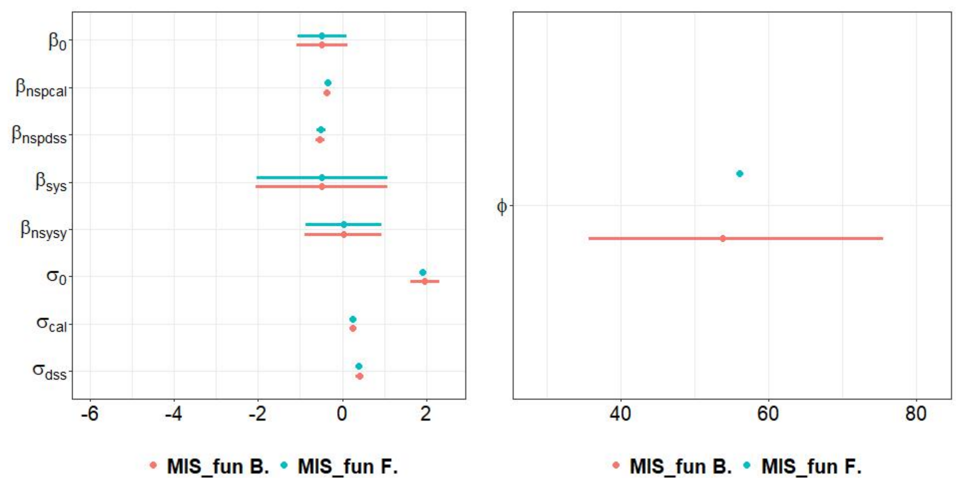
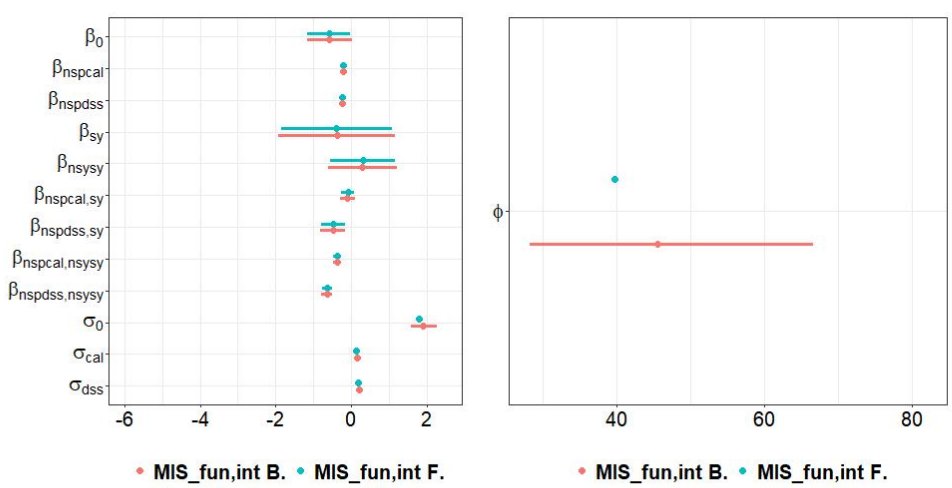


(g)



(h)



(i)

Figure S12. **Sensitivity analysis for MIS models**. Bayesian parameter estimates (in pink) vs. frequentist parameter estimates (in blue) for the (a) MIS_0, (b) MIS_{loc}, (c) $MIS_{loc,int}$, (d) MIS_{crop}, (e) $MIS_{crop,int}$, (f) MIS_{pat}, (g) $MIS_{pat,int}$, (h) MIS_{fun} and (i) $MIS_{fun,int}$ models. Bayesian parameter estimates are summarised by the mean and the 95% credible interval (95% CrI). Frequentist parameter estimates are summarised by the "estimate" and the 95% confidence interval (95% CI). Model specifications are displayed in Table S7.

Supplementary Tables

Table S1. List of publications and experiments included in the meta-analysis. Publications are identified by their corresponding reference and a code identifier. Experiments are characterised by their identifier and the number of plots for each fungicide strategy (untreated, calendar and DSS).

Publication		Experiment	Plots		
Reference	**id**	**id**	**Untreated**	**Calendar**	**DSS**
Brown-Rytlewski et al.[1]	A	A1	1	1	2
Brown-Rytlewski et al.[2]	B	B1	1	1	2
Brown-Rytlewski et al.[3]	C	C1	1	1	2
Brown-Rytlewski et al.[4]	D	D1	1	1	2
Babadoost[5]	E	E1	1	2	2
		E2	1	2	2
Babadoost[6]	F	F1	1	2	2
		F2	1	2	2
Gleason et al.[7]	G	G1	1	1	4
		G2	1	1	4
Hovius and McDonald[8]	H	H1	1	1	1
		H2	1	1	1
		H3	1	1	1
		H4	1	1	1
		H5	1	1	1
McDonald and Hovious[9]	I	I1	1	1	1
		I2	1	1	1
McDonald et al.[10]	J	J1	1	1	1
Averre et al.[11]	K	K1	1	1	1
Llorente et al.[12]	L	L1	1	1	2
		L2	1	1	1
		L3	1	1	1
		L4	1	1	2
		L5	1	1	2
		L6	1	1	1
		L7	1	1	2
		L8	1	1	1
		L9	1	1	1
		L10	1	1	1
		L11	1	1	1
Bhatia et al.[13]	M	M1	1	1	3
		M2	1	1	3
		M3	1	1	3
		M4	1	1	3
Byrne et al.[14]	N	N1	1	3	1
		N2	1	3	1
		N3	1	3	1
		N4	1	3	1
		N5	1	3	1
		N6	1	3	1
		N7	1	3	1
Montesinos et al.[15]	O	O1	1	1	3
		O2	1	1	2
Peres and Timmer[16]	P	P1	1	1	3
		P2	1	1	2
		P3	1	2	2

Wu et al.[17]	Q	Q1	1	1	1
		Q2	1	1	2
		Q3	1	1	2
Louws et al.[18]	R	R1	1	1	4
		R2	1	1	4
		R3	1	1	5
		R4	1	1	4
		R5	1	1	4
		R6	1	1	5
		R7	1	1	4
		R8	1	1	4
		R9	1	1	5
Rasiukevivciute et al.[19]	S	S1	1	1	1
		S2	1	1	1
		S3	1	1	1
		S4	1	1	1
		S5	1	1	1
		S6	1	1	1
Rosli et al.[20]	T	T1	1	1	1
		T2	1	1	1
		T3	1	1	1
		T4	1	1	1
		T5	1	1	1
		T6	1	1	1
		T7	1	1	1
		T8	1	1	1
[a]Holcman et al.[21]	U	U1	1	1	3
		U2	1	1	3
[a]Zhang et al.[22]	V	V1	1	1	1
		V2	1	1	1
		V3	1	1	1
		V4	1	1	1
		V5	1	1	1
		V6	1	1	1
TOTAL			80	99	149

[a] The sample sizes for the experiments in Holcman et al.[21] and Zhang et al.[22] were obtained through personal communication with the authors

Table S2. List of publications and DSSs included in the meta-analysis. Publications are identified by their corresponding reference and a code identifier. DSSs are characterised by the number of plots in which were applied, the DSS name and the environmental variables used to predict disease risk.

Publication		DSSs		Environmental variables					
Reference	**id**	**No. plots**	**Name**	**Air Temperature (° C)**	**Leaf Wetness duration (hours)**	**Rainfall (mm)**	**Relative Humididity (%)**	**Solar Radiation (KJ m^{-2})**	**Wind Speed (m s^{-1})**
Brown-Rytlewski et al.[1]	A	1	DonCast[23]	1	0	1	1	0	0
		1	Penn State FHB model[24]	1	0	1	1	0	0
Brown-Rytlewski et al.[2]	B	1	DonCast[23]	1	0	1	1	0	0
		1	Penn State FHB model[24]	1	0	1	1	0	0
Brown-Rytlewski et al.[3]	C	1	DonCast[23]	1	0	1	1	0	0
		1	Penn State FHB model[24]	1	0	1	1	0	0
Brown-Rytlewski et al.[4]	D	1	DonCast[23]	1	0	1	1	0	0
		1	Penn State FHB model[24]	1	0	1	1	0	0
Babadoost[5]	E	4	LWH	0	1	0	0	0	0
Babadoost[6]	F	4	LWH	0	1	0	0	0	0
Gleason et al.[7]	G	8	LWH	0	1	0	0	0	0
Hovius and McDonald[8]	H	5	Forecasting System	1	1	0	0	0	0
McDonald and Hovious[9]	I	2	Forecasting System	1	1	0	0	0	0
McDonald et al.[10]	J	1	BremCast	1	1	0	0	1	0
Averre et al.[11]	K	1	CFWV[25]	1	0	1	0	0	0
Llorente et al.[12]	L	15	BSPcast	1	1	0	0	0	0
Bhatia et al.[13]	M	12	Alter-Rater	1	1	0	1	0	0
Byrne et al.[14]	N	7	Tom-Cast	1	1	0	0	0	0
Montesinos et al.[15]	O	5	FAST	1	1	1	1	0	0
Peres and Timmer[16]	P	7	Alter-Rater	1	1	0	1	0	0
Wu et al.[17]	Q	5	OS	1	1	0	1	1	1
Louws et al.[18]	R	39	Tom-Cast	1	1	0	0	0	0
Rasiukevivciute et al.[19]	S	6	iMETOS	1	1	0	1	0	0
Rosli et al.[20]	T	8	SBFS Warning system	0	0	1	0	0	0
		2	3-10 rule	1	0	0	1	0	0
Holcman et al.[21]	U	2	Ma25	1	1	0	0	0	0
		2	Ma75	1	1	0	0	0	0
Zhang et al.[22]	V	6	AFR-StAS	1	1	0	0	0	0

Table S3. Moderator variables description: variable name, definition, codification and absolute and relative frequencies (at experiment level) for each variable category.

Variable	Definition	Codification	Abs. freq.	Rel. freq.
Location	Continental location of the experiments:			
	• South America (Brazil)	sa	5	0.06
	• North America (USA, Canada)	na	56	0.70
	• Europe (Italy, Lithuania, Spain)	eu	19	0.24
Crop	Crop types:			
	• Non-woody (wheat, asparagus, lettuce, strawberry, tomato)	nwd	44	0.55
	• Woody (apple, pear, grape, mandarin)	wd	36	0.45
Pathogen	Class taxonomic rank:			
	• Dothideomycetes (*Alternaria alternata*, *A. solani*, *Stemphylium vesicarium*, *Cercospora asparagii*, *Schizothyrium jamaicense*, *Peltaster fructicola*)	do	38	0.47
	• Sordariomycetes (*Fusarium graminearum*, *Colletotrichum coccodes*)	so	14	0.18
	• Leotiomycetes (*Botrytis cinerea*)	le	12	0.15
	• Agaricomycetes (*Rhizoctonia solani*)	ag	3	0.04
	• Oomycetes (*Bremia lactucae*, *Plasmopara viticola*)	oo	13	0.16
Fungicide	Type of fungicide:			
	• Non-systemic (captan, mancozeb, maneb, thiram, copper hydroxide, chlorothalonil, fludioxonil)	nsy	42	0.52
	• Systemic (tebuconazole, thiophanate-methyl, kresoxim-methyl, pyraclostrobin, trifloxystrobin, fosetyl-Al, metalaxyl, procymidone, boscalid, cyprodinil)	sy	7	0.09
	• Non-systemic/systemic	nsysy	31	0.39

Table S4. List of publications included in the meta-analysis, source and search string.

Publication	Source	Search String
Brown-Rytlewski et al.[1]	F & N Tests	Forecasting
Brown-Rytlewski et al.[2]	F & N Tests	Forecasting
Brown-Rytlewski et al.[3]	F & N Tests	Forecasting
Brown-Rytlewski et al.[4]	F & N Tests	Forecasting
Babadoost[5]	F & N Tests	Warning
Babadoost[6]	F & N Tests	Warning
Gleason et al.[7]	F & N Tests	Warning
Hovius and McDonald[8]	F & N Tests	Forecasting
McDonald and Hovius[9]	F & N Tests	Forecasting
McDonald et al.[10]	F & N Tests	Forecasting
Averre et al.[11]	F & N Tests	Hard copies
Llorente et a.[12]	WoS	Other references
Bhatia et al.[13]	WoS	Other references
Byrne et al.[14]	WoS	Other references
Montesinos et al.[15]	WoS	Other references
Peres and Timmer[16]	WoS	Other references
Wu et al.[17]	WoS	(crop OR plant) AND disease AND (fungus OR fungi OR fungal OR fungicide) AND (forecasting OR warning OR prediction OR predictive) AND (decision-support OR decision OR support OR treatment OR model OR system) AND (weekly OR calendar OR daily) AND (Comparison)
Louws et al.[18]	WoS	(crop OR plant) AND disease AND (fungus OR fungi OR fungal OR fungicide) AND (forecasting OR warning OR prediction OR predictive) AND (decision-support OR decision OR support OR treatment) AND (weekly OR calendar OR daily) AND(model OR system)
Rasiukevivciute et al.[19]	WoS	(crop OR plant) AND disease AND (fungus OR fungi OR fungal OR fungicide) AND (forecasting OR warning OR prediction OR predictive) AND (decision-support OR decision OR support OR treatment) AND(model OR system)
Rosli et al.[20]	WoS	(crop OR plant) AND (disease) AND (fungal OR fungi OR fun- gus)

		AND (forecasting OR warning OR prediction) AND decision-support
Holcman et al.[21]	WoS	(crop OR plant) AND disease (fungus OR fungi OR fungal OR fungicide) AND (forecasting OR warning OR prediction OR predictive) AND (decision-support OR decision OR support OR treatment) AND (weekly OR calendar OR daily) AND(model OR system) AND (incidence)
Zhang et al.[22]	WoS	(crop OR plant) AND disease (fungus OR fungi OR fungal OR fungicide) AND (forecasting OR warning OR prediction OR predictive) AND (decision-support OR decision OR support OR treatment) AND (weekly OR calendar OR daily) AND(model OR system) AND (incidence)

Table S5. Statistical models tested for the MI meta-analysis. The models including moderator variables (MI_{loc}, $MI_{loc,int}$, MI_{crop}, $MI_{crop,int}$, MI_{pat}, $MI_{pat,int}$, MI_{fun}, $MI_{fun,int}$) were developed from the baseline model MI_0. Notation is detailed in the Methods section.

Model	Fixed-effects	Random effect	Model definition
MI_0	• Fungicide strategies (untreated, calendar, DSS) at plot level	Experiment level	$\text{logit}(\mu_{ij}) = (\beta_0 + b_{\texttt{0(i)}}) + (\beta_{\texttt{cal}} + b_{\texttt{cal(i)}})I_{\texttt{cal(ij)}} + (\beta_{\texttt{dss}} + b_{\texttt{dss(i)}})I_{\texttt{dss(ij)}}$
MI_{loc}	• Fungicide strategies at plot level • Continental location at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = MI_0 + \beta_{\texttt{na}} I_{\texttt{na(i)}} + \beta_{\texttt{eu}} I_{\texttt{eu(i)}}$
$MI_{loc,int}$	• Fungicide strategies at plot level • Continental location at exp. level • Interaction between fungicide strategies and continental location	Experiment level	$\text{logit}(\mu_{ij}) = MI_{loc} + \beta_{\texttt{cal,na}} I_{\texttt{cal,na(ij)}} + \beta_{\texttt{dss,na}} I_{\texttt{dss,na(ij)}} + \beta_{\texttt{cal,eu}} I_{\texttt{cal,eu(ij)}} + \beta_{\texttt{dss,eu}} I_{\texttt{dss,eu(ij)}}$
MI_{crop}	• Fungicide strategies at plot level • Crop types at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = MI_0 + \beta_{\texttt{wd}} I_{\texttt{wd(i)}}$
$MI_{crop,int}$	• Fungicide strategies at plot level • Crop types at exp. level • Interaction between fungicide strategies and crop types	Experiment level	$\text{logit}(\mu_{ij}) = MI_{crop} + \beta_{\texttt{cal,wd}} I_{\texttt{cal,wd(ij)}} + \beta_{\texttt{dss,wd}} I_{\texttt{dss,wd(ij)}}$
MI_{pat}	• Fungicide strategies at plot level • Pathogen types at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = MI_0 + \beta_{\texttt{so}} I_{\texttt{so(i)}} + \beta_{\texttt{le}} I_{\texttt{le(i)}} + \beta_{\texttt{ag}} I_{\texttt{ag(i)}} + \beta_{\texttt{oo}} I_{\texttt{oo(i)}} +$
$MI_{pat,int}$	• Fungicide strategies at plot level • Pathogen types at exp. level • Interaction between fungicide strategies and pathogen types	Experiment level	$\text{logit}(\mu_{ij}) = MI_{pat} + \beta_{\texttt{cal,so}} I_{\texttt{cal,so(i)}} + \beta_{\texttt{dss,so}} I_{\texttt{dss,so(i)}} + \beta_{\texttt{cal,le}} I_{\texttt{cal,le(i)}} + \beta_{\texttt{dss,le}} I_{\texttt{dss,le(i)}} + \beta_{\texttt{cal,ag}} I_{\texttt{cal,ag(i)}} + \beta_{\texttt{dss,ag}} I_{\texttt{dss,ag(i)}} \beta_{\texttt{cal,oo}} I_{\texttt{cal,oo(i)}} + \beta_{\texttt{dss,oo}} I_{\texttt{dss,oo(i)}} +$
MI_{fun}	• Fungicide strategies at plot level • Fungicide types at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = MI_0 + \beta_{\texttt{nsy}} I_{\texttt{nsy(i)}} + \beta_{\texttt{synsy}} I_{\texttt{synsy(i)}}$
$MI_{fun,int}$	• Fungicide strategies at plot level • Fungicide types at exp. level • Interaction between fungicide strategies and fungicide types	Experiment level	$\text{logit}(\mu_{ij}) = MI_{fun} + \beta_{\texttt{cal,nsy}} I_{\texttt{cal,nsy(i)}} + \beta_{\texttt{dss,nsy}} I_{\texttt{dss,nsy(i)}} + \beta_{\texttt{cal,synsy}} I_{\texttt{cal,synsy(i)}} + \beta_{\texttt{dss,synsy}} I_{\texttt{dss,synsy(i)}}$

Table S6. K-fold cross-validation model selection values for the MI models.

Model	elpd_kfold	SE_elpd_kfold	Δelpd_kfold (A)[a]	ΔSE_elpd_kfold (B)[b]	$\left\lvert\frac{A}{B}\right\rvert$
MI_0	-1689.5	28.2	–	–	–
MI_{loc}	-1697.4	29.3	7.9	12.9	0.6
$MI_{loc,int}$	-1695.2	29.6	5.7	13.2	0.4
MI_{crop}	-1694.0	28.2	4.5	1.6	2.8
$MI_{crop,int}$	-1693.5	29.7	4.1	4.7	0.9
MI_{pat}	-1691.7	27.2	2.3	3.8	0.6
$MI_{pat,int}$	-1690.6	28.4	1.2	4.1	0.3
MI_{fun}	-1680.4	29.4	-9.0	5.1	1.8
$MI_{fun,int}$	-1677.8	29.2	-11.6	5.5	2.1

[a] Difference between the baseline model (MI_0) and those with moderator variables

[b] Differences in models are considered not meaningful if $\left\lvert\frac{A}{B}\right\rvert \leqslant 4$

Table S7. Statistical models tested for the MIS meta-analysis. The models including moderator variables (MIS_{loc}, $\text{MIS}_{loc,int}$, MIS_{crop}, $\text{MIS}_{crop,int}$, MIS_{pat}, $\text{MIS}_{pat,int}$, MIS_{fun}, $\text{MIS}_{fun,int}$) were developed from the baseline model MIS_0. Notation is detailed in the Methods section.

Model	Fixed-effects	Random effect	Model definition
MIS_0	• Interaction between fungicide strategies (untreated, calendar, DSS) and number of sprays at plot level[a]	Experiment level	$\text{logit}(\mu_{ij}) = (\beta_0 + b_{\texttt{0(i)}}) + (\beta_{\texttt{nspcal}} + b_{\texttt{cal(i)}})\texttt{nspcal(ij)}\, I_{\texttt{cal(ij)}} + (\beta_{\texttt{nspdss}} + b_{\texttt{dss(i)}})\texttt{nspdss(ij)}\, I_{\texttt{dss(ij)}}$
MI_{loc}	• Interaction between fungicide strategies and number of sprays at sub-exp. level[a] • Continental location at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_0 + \beta_{\texttt{na}} I_{\texttt{na(i)}} + \beta_{\texttt{eu}} I_{\texttt{eu(i)}}$
$\text{MIS}_{loc,int}$	• Interaction between fungicide strategies and number of sprays at plot level[a] • Continental location at exp. level • Interaction between the above mentioned fixed effects	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_{loc} + \beta_{\texttt{nspcal,na}}\texttt{nspcal(ij)}\, I_{\texttt{cal,na(ij)}} + \beta_{\texttt{nspdss,na}}\texttt{nspdss(ij)}\, I_{\texttt{dss,na(ij)}} + \beta_{\texttt{nspcal,eu}}\texttt{nspcal(ij)}\, I_{\texttt{cal,eu(ij)}} + \beta_{\texttt{nspdss,eu}}\texttt{nspdss(ij)}\, I_{\texttt{dss,eu(ij)}}$
MIS_{crop}	• Interaction between fungicide strategies and number of sprays at plot level[a] • Crop types at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_0 + \beta_{\texttt{wd}} I_{\texttt{wd(i)}}$
$\text{MIS}_{crop,int}$	• Interaction between fungicide strategies and number of sprays at plot level[a] • Crop types at exp. level • Interaction between the above mentioned fixed effects	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_{crop} + \beta_{\texttt{nspcal,wd}}\texttt{nspcal(ij)}\, I_{\texttt{cal,wd(ij)}} + \beta_{\texttt{nspdss,wd}}\texttt{nspdss(ij)}\, I_{\texttt{dss,wd(ij)}}$
MIS_{pat}	• Interaction between fungicide strategies and number of sprays at plot level[a] • Pathogen types at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_0 + \beta_{\texttt{so}} I_{\texttt{so(i)}} + \beta_{\texttt{le}} I_{\texttt{le(i)}} + \beta_{\texttt{ag}} I_{\texttt{ag(i)}} + \beta_{\texttt{oo}} I_{\texttt{oo(i)}}$
$\text{MIS}_{pat,int}$	• Interaction between fungicide strategies and number of sprays at plot level[a] • Pathogen types at exp. level • Interaction between the above mentioned fixed effects	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_{dis} + \beta_{\texttt{nspcal,so}}\texttt{nspcal(ij)}\, I_{\texttt{cal,so(i)}} + \beta_{\texttt{nspdss,so}}\texttt{nspdss(ij)}\, I_{\texttt{dss,so(i)}} + \beta_{\texttt{nspcal,le}}\texttt{nspcal(ij)}\, I_{\texttt{cal,le(i)}} + \beta_{\texttt{nspdss,le}}\texttt{nspdss(ij)}\, I_{\texttt{dss,le(i)}} + \beta_{\texttt{nspcal,ag}}\texttt{nspcal(ij)}\, I_{\texttt{cal,ag(i)}} + \beta_{\texttt{nspdss,ag}}\texttt{nspdss(ij)}\, I_{\texttt{dss,ag(i)}} + \beta_{\texttt{nspcal,oo}}\texttt{nspcal(ij)}\, I_{\texttt{cal,oo(i)}} + \beta_{\texttt{nspdss,oo}}\texttt{nspdss(ij)}\, I_{\texttt{dss,oo(i)}}$
MIS_{fun}	• Interaction between fungicide strategies and number of sprays at plot level[a] • Fungicide types at exp. level	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_0 + \beta_{\texttt{nsy}} I_{\texttt{nsy(i)}} + \beta_{\texttt{synsy}} I_{\texttt{synsy(i)}}$
$\text{MIS}_{fun,int}$	• Interaction between fungicide strategies and number of sprays at plot level[a] • Fungicide types at exp. level • Interaction between the above mentioned fixed effects	Experiment level	$\text{logit}(\mu_{ij}) = \text{MIS}_{fun} + \beta_{\texttt{nspcal,nsy}}\texttt{nspcal(ij)}\, I_{\texttt{cal,nsy(i)}} + \beta_{\texttt{nspdss,nsy}}\texttt{nspdss(ij)}\, I_{\texttt{dss,nsy(i)}} + \beta_{\texttt{cal,synsy}}\texttt{nspdss(ij)}\, I_{\texttt{cal,synsy(i)}} + \beta_{\texttt{nspdss,synsy}}\texttt{nspdss(ij)}\, I_{\texttt{dss,synsy(i)}}$

[a] Number of sprays is a "nested" variable as it only applies for the calendar and DSS fungicide strategies, but not to the untreated control. This was specified in the MIS model formulation by putting this nested variable only as an interaction with the fungicide strategy indicator, but not as a main effect.

Table S8. K-fold cross-validation model selection values for the MIS models.

Model	elpd_kfold	SE_elpd_kfold	Δelpd_kfold (A)[a]	ΔSE_elpd_kfold (B)[b]	$\left\lvert\frac{A}{B}\right\rvert$
MIS_0	-1731.5	30.6	–	–	–
MIS_{loc}	-1745.3	31.7	14.3	14.1	1.0
$MIS_{loc,int}$	-1741.1	31.6	10.2	15.7	0.6
MIS_{crop}	-1730.6	28.9	-0.4	6.0	0.1
$MIS_{crop,int}$	-1734.0	29.8	3.0	5.0	0.6
MIS_{pat}	-1724.2	29.2	-6.8	6.4	1.1
$MIS_{pat,int}$	-1720.3	30.1	-10.6	7.3	1.5
MIS_{fun}	-1735.3	30.4	4.3	1.6	2.8
$MIS_{fun,int}$	-1713.1	33.9	-17.9	12.9	1.4

[a] Difference between the baseline model (MIS_0) and the models including moderator variables.

[b] Difference in models are considered not meaningful if $\left\lvert\frac{A}{B}\right\rvert \leqslant 4$

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